

Quantitative Analysis of Uranium Isotopes in the Water and Soil of Eastern Afghanistan and Iraq Following the Use of Radioactive Weapons in the Military Operations Enduring Freedom (OEF) and Iraqi Freedom (OIF)*

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The purpose of this study is to determine the concentration and precise isotopic ratios of four uranium isotopes (^{234}U , ^{235}U , ^{236}U , ^{238}U) in the water and soil in Afghanistan and Iraq after the use of radioactive weapons in the military operations OEF and OIF.

Water and soil samples were selected from sites of military conflict in Jalalabad, the area of Kabul, Afghanistan and in Baghdad, Basra, and Nasiriyah, Iraq. Soils (fraction < 150 micrometer) were separated and leached in hot aqua regia over 48 hours. Water samples were evaporated, organic matter oxidized, and the residue dissolved in concentrated nitric acid at 120°C over 48 hours. Uranium was separated and purified in all samples by ion-exchange chromatography followed by isotopic analysis using a double-focusing Thermo Finnigan Neptune multi-collector ICP-MS. The isotope dilution method, via the addition of a ^{233}U tracer, was used to measure the uranium concentration.

Four of six water samples from Iraq have a mean value ratio of $^{238}\text{U}:^{235}\text{U}$ of 138.04 which suggests natural uranium and ^{236}U below the detectable level (< 0.3 pg/L). Two samples have a $^{238}\text{U}:^{235}\text{U}$ ratio of 193.6 to 427.8 and a $^{236}\text{U}:^{238}\text{U}$ ratio of 1.0×10^{-5} to 2.4×10^{-5} . These values are indicative of contamination with depleted uranium (DU). The concentration of total uranium is 5 to 42 µg/L in the DU contaminated water and 0.6 to 1.9 µg/L in the samples with a natural uranium isotope composition. Two of 4 analysed water samples from Afghanistan have only slightly elevated $^{238}\text{U}:^{235}\text{U}$ ratio suggesting a very small proportion of DU (0.1 and 0.3%, respectively). The uranium of the four samples varies from 1 to 22 µg/L.

All analysed fine-fractions of soils from Iraq have a DU signature, with a DU proportion of 0.4 to about 100%. ^{236}U is present in all soil fine-fraction, from 0.1 ppt (parts per trillion) to 12.4 ppb (parts per billion). ^{235}U and ^{234}U are both depleted relative to ^{238}U and clear correlations between $^{238}\text{U}:^{235}\text{U}$ and $^{234}\text{U}:^{238}\text{U}$ and $^{236}\text{U}:^{238}\text{U}$ exist. Variation of the $^{236}\text{U}:^{238}\text{U}$ at high $^{238}\text{U}:^{235}\text{U}$ ratios (> 480) suggest variable amounts of ^{236}U in the source of contamination. Fourteen soil samples from Afghanistan had a mean concentration of 4.95 mg/kg.

Our results demonstrate the presence of elevated levels of uranium in soils and ^{236}U in some of the water samples of Jalalabad and Kabul areas, Afghanistan after OEF as well as in the water and soil of Baghdad, Basra, and Nasiriyah, Iraq after OIF. In addition, natural uranium was found in water samples from Iraq. DU was identified in some water and soil samples from Iraq. Minimal trace amounts of DU were found in the water samples from Afghanistan. The analysis of soil samples from Afghanistan for DU led to inconclusive results and needs further investigation. The contamination of water and soil may be a consequence of the use of uranium weapons by Allied Forces, which set free uranium containing aerosols upon impact.

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